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Illegal tambaqui fishing in the Negro, Solimões and Amazonas Rivers: an analysis on the effects of closed season law

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ABSTRACT

Due to the decline in fish stocks in Brazil, mainly in the Amazon Basin, the Closed Fishing Season Law was implemented to help fisheries recover and protect fish habitat. Tambaqui (*Colossoma macropomum*) is one of the main overexploited fish species and there is concern about its decline in many Amazonian rivers. Therefore, in order to investigate the effectiveness of the Closed Fishing Season Law as it applies to tambaqui, seizure data compiled by IBAMA (Brazilian Institute of Environmental Protection) was analyzed for the period 1993 to 2012 (20 years) for the Negro, Solimões and Amazonas rivers. Although the results of this study showed variations in the volume of tambaqui seizures among the three different rivers analyzed over a 20-year period, these variations were small in comparison to the differences found between the 10-year periods before and after implementation of the Closed Fishing Season Law. Overall, there was a 24.4% decrease in the volume of tambaqui seized after implementation of the Law, which can be attributed to a number of possible reasons: 1) reduction of tambaqui stocks in the area of study; 2) occurrence of great floods and dry periods influenced by the natural phenomena El Niño and La Niña, which strongly affected fish stocks in 2002-2003 and 2009, respectively; 3) poor enforcement of regulations, due to reductions in IBAMA personnel and; 4) difficult to patrol such a large area, including many remote locations. However, notwithstanding the noted overall decrease, the results suggest that implementation of the Closed Fishing Season Law with its corresponding compensation payments to fishers did not end up dramatically improving the protection of tambaqui stocks and may have even encouraged more people to enter into the fishery to benefit from the payments.

Keywords: Fishery stocks; fisheries; closed season compensation.

A pesca ilegal do tambaqui nos Rios Negro, Solimões e Amazonas: uma análise dos efeitos da lei do defeso

RESUMO

Com o declínio dos estoques pesqueiros no Brasil, sobretudo na bacia Amazônica, foi criada a Lei do Defeso para auxiliar na recuperação dos estoques pesqueiros e na proteção de seus ambientes. O tambaqui (*Colossoma macropomum*) é uma das espécies de peixes mais sobreexplotada, onde já se reconhece a sua diminuição em muitos rios da Amazônia. Sendo assim, com o foco de investigar a eficácia do emprego da Lei do Defeso e sua aplicabilidade na defesa do tambaqui, dados das apreensões registradas pelo IBAMA (Instituto Brasileiro do Meio Ambiente) foram analisados para o período de 1993 a 2012 (20 anos), ocorridas nos rios Negro, Solimões e Amazonas. Os resultados mostraram que incidiram variações no número de apreensões de tambaquis entre os diferentes rios estudados durante o período de 20 anos, mas essas variações foram fracas, quando comparadas aos períodos de 10 anos antes e após a criação da Lei do Defeso. No entanto, foi registrado também, uma diminuição de 24,4% no número de infrações após a implementação da referida Lei, o que pode ser atribuído a várias possibilidades: 1) diminuição dos estoques da espécie na área do estudo; 2) ocorrência de grandes cheias e secas influenciadas por fenômenos naturais como o El Niño e a La Niña, que impactaram fortemente os estoques de peixes nos períodos de 2002-2003 e 2009, respectivamente; 3) reduzido efetivo de pessoal fiscalizador, em virtude da diminuição do efetivo de pessoal no IBAMA; e 4) dificuldades em fiscalizar regiões muito extensas, incluindo os locais remotos. Sendo assim, mesmo com a perceptível queda no número de apreensões de tambaqui na região do estudo, os resultados sugerem que o emprego da Lei do Defeso e do seu referido seguro para os pescadores, não alcançaram a finalidade desejada, e ainda, podem estar influenciando negativamente na sustentabilidade dos estoques de tambaquis da região, principalmente pelo incentivo ao ingresso de novos pescadores em virtude da oferta do seguro.

Palavras-chave: Estoque pesqueiro, pescarias, seguro defeso.

Introduction

The Amazon basin hosts extraordinary fish diversity (REIS et al., 2016), with more than 3,300 species identified to date (REIS et al., 2003; ISAAC et al., 2012; FROESE; PAULY, 2018). However, the fish stocks of some subsistence and commercially-exploited species are suffering from increasing depletion, due to both overfishing and environmental factors (BARTHEM; FABRÉ, 2004; SOUSA et al., 2017). Both subsistence and commercial fisheries employ nets and fishing strategies in accordance with target species, fishing grounds and hydrological season (BATISTA, 1998; BARTHEM; FABRÉ, 2004; LOPES et al., 2016). Not only is fishing a necessary activity for riverine dwellers, who depend on this protein source for their livelihoods and sustenance (DORIA et al., 2008; SOUSA et al., 2017), but it also provides income for professional fishers throughout the Amazonian region (ALMEIDA et al., 2001).

Commercial fisheries in the Amazon produce approximately 250 thousand tons of fish per year (FREITAS, et al., 2012), which are mainly comprised of 12 species (BARTHEM; FABRÉ, 2004), that include migratorial Characiformes (LOPES; FREITAS, 2019). Importantly, an estimated 21.7% of this fish production is commercialized in the city of Manaus in Amazonas State (CARDOSO et al.,

2004; PARENTE; BATISTA, 2005; IBAMA, 2008), where a significant portion originates from the Solimões River and its tributaries (ISAAC; RUFFINO, 1996; SILVA et al., 2019).

Many studies over the last 20 years have reached the conclusion that commercial fishing in the region around Manaus has resulted in overfishing and exceedance of the maximum sustainable yield of many fish stocks (BATISTA; PETRERE Jr., 2003; SOUSA; FREITAS, 2010; CAMPOS et al., 2015). This overfishing has consisted of an unsustainable capture of principally large individuals (usually adult and breeding fish), which has weakened the natural replacement of exploited stocks (ARAÚJO-LIMA; GOULDING, 1998; SÁNCHEZ-BOTERO et al., 2006; SOUSA; FREITAS, 2010).

Reductions in fish stocks have been noticed by Amazonian fishing communities since the 1970s, when average catch rates of some species of commercial interest had begun to diminish. Consequently, this raised questions about the possibility of overfishing (SÁNCHEZ-BOTERO et al., 2006), especially due to commercial fishing fleets with iced holds being able to travel long distances (SOUSA; FREITAS, 2010) to fish out an area of target species with high commercial value, before moving on to other areas, where the process would be repeated (MERONA, 1995; ISAAC; RUFFINO, 1996; SOUSA; FREITAS, 2010).

As a result of overfishing of commercial fish species by regional fleets, including migrating fish species (VIEIRA et al., 1999; SÁNCHEZ-BOTERO et al., 2006; CORRÊA et al., 2014), catch regulations were implemented in 1996, aimed at minimizing the effects of uncontrolled fishing and to promote conservation of the remaining fish stocks. Thus, a normative resolution was established through IBAMA'S (Brazilian Institute of Environmental Protection) Ordinance No. 8 on February 2, 1996 (IBAMA, 1996), which stipulated the minimum size required for tambaqui catches (55 cm) and the prohibition of some types of fishing gear. However, this resolution did not contain regulations for the maintenance of the other fish stocks.

Two hydrological periods of the Amazonas River that appear critical to the life cycles of fish species include the rising stage (March and April) and low water period (August and September). During the rising water period, some fish species leave their birth environment and migrate upriver in search of food resources, refuge and adequate habitat to reproduce (SOUSA; FREITAS, 2010; CORRÊA et al., 2014; SOUSA et al., 2017).

Therefore, in order to reduce the impact of fishing on stocks during important reproduction periods, management strategies such as the Closed Fishing Season Law were developed (BORDALO; CRUZ, 2011). This is also known as the "piracema ordinance" (Ordinance No. 142/2002, of October 30th, 2002, IBAMA), which was implemented to protect natural fish reproduction in Brazilian hydrographic basins through size restrictions, fish quotas and the prohibition of fishing activity in certain places.

In compensation for reductions in family income due to fishing prohibitions during the Closed Fishing Season period in protected areas, unemployment benefits were granted to fishers through implementation of Law No. 10.779 on November 25th, 2003, which aims to prevent detrimental impacts to fish stocks and maintenance of populations.

During the Closed Fishing Season period in the Central Amazon, it is strictly prohibited to catch, carry, and/or commercialize migratory fish species, such as curimatã *Prochilodus argenteus* (SPIX; AGASSIZ, 1829), pacu *Piaractus mesopotamicus* (HOLMBERG, 1887), matrinxã (*Brycon cephalus*) (GÜNTHER, 1869) and tambaqui *Colossoma macropomum* (CUVIER, 1818). It is important to note that tambaqui is classified as the second largest scaly fish in the Amazon basin (GOULDING; CARVALHO, 1982) and is currently considered one of the most important and profitable commercial species, due to high demand by the consumer market (ARAÚJO-LIMA; GOULDING, 1997; OLIVEIRA; SOUSA, 2017). However, according to the results of studies over the last 25 years, its stocks in many areas have been severely overfished (GOULDING; CARVALHO, 1982; SOUSA; FREITAS, 2010; CAMPOS et al., 2015), leading to concerns about its sustainability as a commercially-fished species.

In order to protect natural stocks, the 55-cm size restriction for tambaqui is important, as this has been determined to be the minimum size of sexual maturation for this species (ARAÚJO-LIMA; GOULDING, 1998). Non-compliance with this regulation and the Closed Fishing Season Law results in seizures of fishing gear, catches and even boats in some cases by the Brazilian Environmental Protection Agency (IBAMA), which is supported by Law No. 7019 of July 24th, 2007 (PARÁ, 2007; SILVA; SADECK, 2011). Detailed records regarding the number of illegal fishing activities and seizures of equipment and catches can be found in IBAMA's arquives.

The objective of the current study was to evaluate the IBAMA records of fish seizures during the period from 1993 to 2012 for the Negro, Solimões and Amazonas river basins, with the purpose of verifying the following: 1) Was there a reduction in infractions and seizures of illegally-fished tambaqui after implementation of the Closed Fishing Season Law in 2003; and 2) Observe the frequency of these occurrences on each river in terms of fishing production. The results generated by this study can be used as a tool to evaluate the positive impacts created by implementation of the Closed Fishing Season Law and, in turn, make recommendations for better control and management of *C. macropomum* stocks in the Amazon basin.

Material and Methods

Study area

The study area comprises the Negro, Solimões, and Amazonas rivers, which are all intricately connected. The city of Manaus is located at the confluence of the Negro and Solimões rivers, which at that point form the Amazonas River (Figure 1).

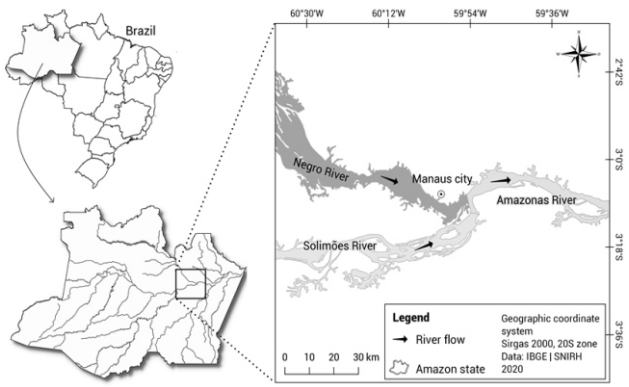

Figure 1. Location of the Negro, Solimões and Amazonas rivers in Amazonas State, where seizures of equipment and catches of illegal tambaqui fishing were executed by IBAMA, Brazil's environmental protection agency.

Data collection

Data was collected in December/2012 regarding tambaqui seizures that occurred on the Solimões, Negro, and Amazonas rivers from 1993 to 2012. This information was compiled from IBAMA databases requested at the office in Manaus, with the authorization number 02005.103474/2017-44.

Data analysis

The data was tabulated and initially analyzed using descriptive statistics in order to obtain average values, standard deviations, and absolute and relative frequencies. After, Pearson's test (considering r and r^2 values) and the regression analysis (y = a + bx) were used to check the linear relation among the seizure rates in tons in relation to the dates of tambaqui seizures in the study area. Also, total seizures in tons (10 years before and after implementation of the Closed Fishing Season Law), when the normality and homogeneity prerequisites were met, were submitted to the Student's t-test in order to check for differences among the assessed averages.

Results

In the period from 1993 to 2012, a total of 616.52 tons of *C. macropomum* were seized from the Solimões, Negro, and Amazonas rivers. Of this total, 62.18% of individuals were confiscated in the 10-year period before implementation of the Closed Fishing Season Law, while 37.82% was confiscated in the 10-year period posteriorly. In the decade before enforcing the Closed Fishing Season Law in 2003, 383.37 tons of tambaqui were confiscated, particularly during 1995 (73.6 t) and 1999 (81.4 t), which showed an increase of 10.6% in only 4 years. For this period, Pearson's analysis showed a positive, although weak linear relation between the seizure rate and occurrence period (r^2 = 0.0097; r = 0.0983; p = 0.7871; y = -2011.96 + 1.0264*x).

In the decade following implementation of the Closed Fishing Season Law, there was a reduction in *C. macropomum* seizures, which totalled 233.16 tons during this period, although a high of 85.4 tons were confiscated in 2009. Furthermore, according to the same analysis, the total number of seizures was also lower (60.93%) than in the previous decade (r^2 = 0.0339; r = 0.1841; p = 0.6106; y = -3316.6526 + 1.6637*x). However, the seizure averages between the two periods (before = 38.33 ± 31.62; after = 23.31 ± 27.35) did not show significant differences when compared using the Student's t-test (t-value = 1.135; df =18; p = 0.270 and Levene p = 0.355) (Figure 2).

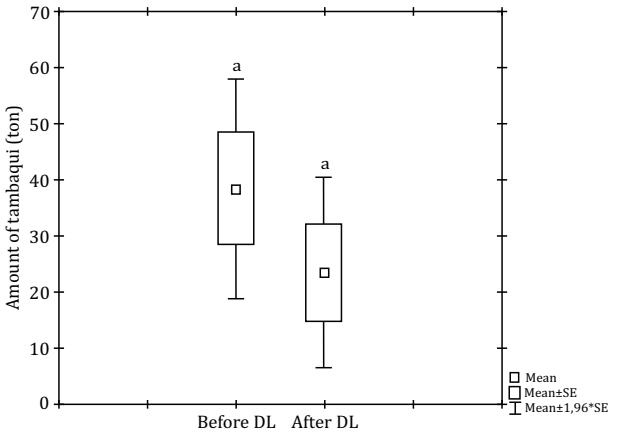

Figure 2. Amount of tambaqui seizures in tons, occurring before and after the Closed Fishing Season or Defense Law (DL) regulations. Equal letters denote, there is not significant differences between the means values when applied to the Student's t-test.

On the other hand, when analyzing the total number of tambaqui seizures in tons during the 20-year sample period using Pearson's analysis method, the following values were determined: r^2 = 0.025; r = -0.158; p = 0.505; y = 1624.053 – 0.7956*x (y = ton, x = years, C.I. – Confidence Interval 0.95), which, apart from 2009, showed a general decline in the volume of confiscated tambaqui catches (Figure 3).

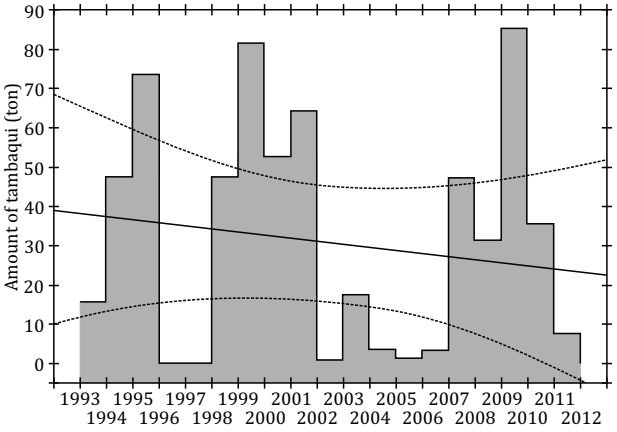

Figure 3. Annual totals of tambaqui seizures (tons) from the Solimões, Negro, and Amazonas rivers over a 20-year period. Dotted lines represent 95% Confidence Intervals, with the solid line showing the linearity of the assessed parameters. There was no seizure data for the years 1996 and 1997.

Among the total number of seizures in tons per river during the study period, the Amazonas River showed a volume of 249.73 tons (annual average of 12.49 t ± 21,07; Coefficient of variation - CV = 168.69), followed by the Negro River with 225.27 t (annual average of 11.26 t ± 16.61; CV = 147.51) and the Solimões River with 141.52 t (annual average of 7.07 t ± 10.72; CV = 151.62). For the Amazonas River, the highest annual volumes of seized tambaqui occurred in 1995 (41.19 t), 1999 (32.01 t), 2007 (33.94 t) and 2009 (83.06 t). The second highest volume of seized tambaqui occurred on the Negro River in a record 4-year period (1998 to 2001), when a total of 140.537 tons of tambaqui were confiscated. The highest annual volumes of seized tambaqui in the Solimões River occurred in 1994 (36.60 t) and 2008 (27.58 t) (Figure 4).

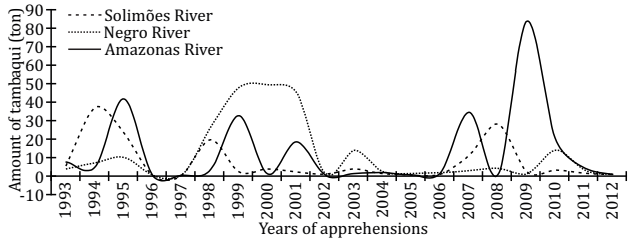

Figure 4. Annual totals of seized tambaqui (tons) from the Solimões, Negro, and Amazonas rivers during the period 1993 to 2012.

When analyzing the volume of tambaqui seized per river using the Pearson's test, the Solimões River (r^2 = 0.267; r = -0.517; p = 0.126; y = 4317.2821 – 2.1567*x) and Amazonas River (r^2 = 0.008; r = -0.089; p = 0.807; y = 885.8502 - 0.4382*x) showed a reduction in the volume seized during the period before implementation of the Closed Fishing Season Law (Figure 5A), while the Negro River showed a higher volume confiscated during the same period (r^2 = 0.274; r = 0.524; p = 0.120; y = -7215.0924 + 3.6214*x). In contrast, for the 10-year period following implementation of the Closed Fishing Season Law, there was an increase in volume of seized tambaqui on the Amazonas River (r^2 = 0.049; r = 0.220; p = 0.540; y = -3873.7228 + 1.9368*x), while there were reductions on the Solimões River (r^2 < 0.001; r = 0.008; p = 0.982; y = -42.0791 + 0.0234*x) and Negro River (r^2 = 0.031; r = -0.177; p = 0.624; y = 599.1493 - 0.2965*x) (Figure 5B).

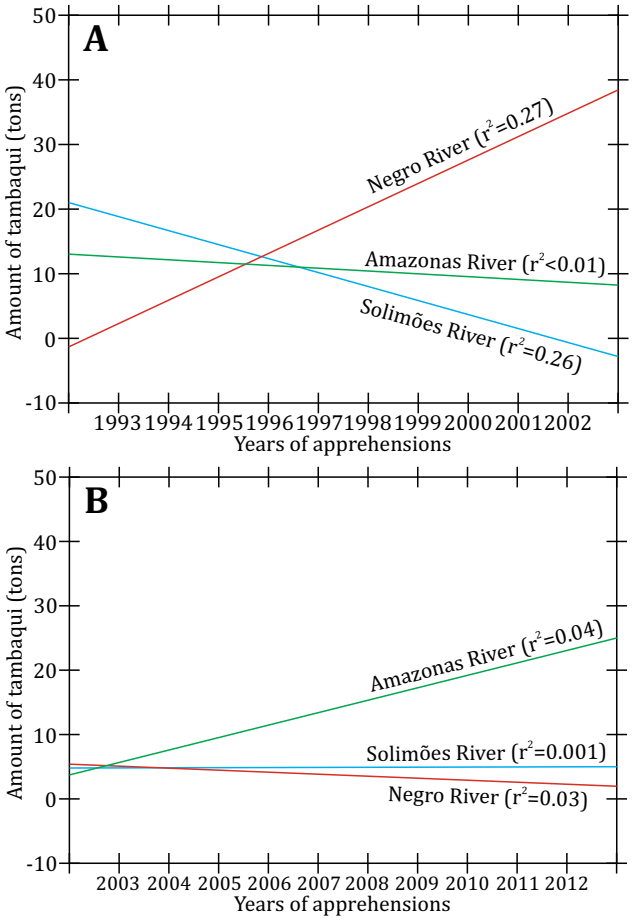

Figure 5. Linear analysis of the volume of tambaquis (tons) seized on the Solimões, Negro, and Amazonas rivers (1993 to 2012). A = data collected in a period of 10 years before the Closed Fishing Season Law, B = data collected in a period of 10 years after the Closed Fishing Season Law.

Discussion

Although regulations have been imposed in order to protect some overexploited Amazonian fish species, it is clear that a considerable number of fishers have continued to use illegal practices or fish during closed seasons (DORIA et al., 2008; CORRÊA et al., 2014; CHAGAS et al., 2015), resulting in the seizure of fishing gear and catches by inspection agents. Furthermore, there is the added element of unregistered fishers, whose clandestine activities have been recorded both before and after implementation of the Closed Fishing Season or Defense Law by IBAMA authorities.

The current study showed an apparent reduction of 24.4% in the total volume of tambaqui seizures in the Amazon over a 10-year period after implementation of the Closed Fishing Season Law in comparison with the decade prior. However, this difference was not significant, due mainly to large variations in standard deviation values. Although the reduction in seizures did not equate to observed increases in tambaqui stocks in the region, there was a noted decrease in fishing activity during the prime reproductive period of tambaqui (November – January) for the years 2005 to 2010 (CORRÊA et al., 2014).

Likewise, in the years just before and soon after implementation of the Law (from 2002 to 2005), records on tambaqui seizures were scant when compared with other years, especially regarding the Amazonas River. However, this may be related to a long El Niño-driven drought at the time that caused a reduction in precipitation in the Amazon basin from 2002 to 2003 (ZENG et al., 2008), which made difficult both fishing activities and inspections by government officials.

Studies in the Amazon have shown that there is both increased fishing effort and fish landings during low water periods (DORIA et al., 2008; CORRÊA et al., 2014; SOUSA et al., 2017), which can be attributed to two main factors: 1) reduction of water surface area, which constricts a higher density of fish into smaller bodies of water, thereby facilitating capture (SOUSA; FREITAS, 2011; CORRÊA et al., 2014); and 2) an increase in the number of fishers during this period, due to the Closed Fishing Season Law being in effect during the rising and high water periods (CORRÊA et al., 2014).

An increase in the number of new fishers who entered into the industry during the last decade could be associated with the Closed Fishing Season Compensation payment, since the main requirement to receive this benefit is to be registered as a fisher. The number of applicants to receive the compensation rose from 13,794 in 2005 to 71,586 in 2012 (MPA, 2013), which was an increase of 519% over 7 years. This factor may have contributed to the results shown in the present study, which demonstrated an increase in the volume (tons) of tambaqui seized on the Amazonas and Solimões rivers over a 3-year period, from 2007 (33.94 t), to 2008 (27.58 t) and 2009 (83.06 t). This could also be one of the prime reasons for reduction of tambaqui stocks in the region, considering that 27.2% of the total of seized fish in the Amazon region in 2015 were *Arapaima gigas* (pirarucu) and tambaqui (CHAGAS et al., 2015). Furthermore, 92.86% of apprehended tambaqui in the medium reach of the Solimões River in the decade following implementation of the Law were found to be below the 55 cm threshold (SÁNCHEZ-BOTERO et al., 2006; SOUSA; FREITAS, 2011).

On the other hand, when evaluating the reasons behind such a high volume of tambaqui seized in 2009, it is important to note that the greatest recorded flood in the Amazon basin occurred that year, which was caused by an exceptional La Niña, bringing heavy rainfall and wide-spread inundation (VALE et al., 2011). As a result, any large flood like in 2009 brings a rise in fish reproduction, as individuals spread out into areas of flooded forest to feed, find refuge, and reproduce (TORRENTE-VILARA, 2003; BARTHEM; FABRÉ, 2004; CORRÊA et al., 2014). This, in turn, makes fishing difficult, leading to low catches (HURD et al., 2016). Therefore, it appears that many fishers disobeyed the Closed Fishing Season regulations that year in a desperate attempt to increase landings and generate some revenue, which drove up the volume of seized fish, many of which were below the limit of 55 cm (DORIA et al., 2008; CORRÊA et al., 2014). Furthermore, illegal fishing was also found in some preservation areas, which are meant to be completely off limits to any kind of exploitation, as these habitats serve as important breeding grounds for juveniles (SOUSA; FREITAS, 2011).

Another problem may be inherent in the indicated threshold size for tambaqui, which appears to be different depending on the sex. For example, ARAÚJO-LIMA and GOLDING (1998) found that the minimum size of sexual maturation for females was 58 cm, while VIEIRA et al. (1999) estimated that it varied between 70 and 112 cm. At the same time, these latter authors determined that the maturity length for tambaqui males varied from 62 to 95 cm. Although the Closed Fishing Season for tambaqui stipulates prohibition of all fishing activity during the months from November to January, which coincides with the period of Characiform reproduction in the lower Amazonas River

(VAZZOLER; MENEZES, 1992; VIEIRA et al., 1999), it may be different in the Solimões and Amazonas rivers, respectively. For instance, NOVOA and RAMOS (1982), studying population dynamics of tambaqui in the Orinoco River basin in Venezuela, detected gonad maturation in male individuals in June, while mature females peaked in August and September.

These discrepancies regarding the sexual maturity sizes of tambaqui individuals have also been noted by riverine populations in the Guaporé river basin in western Brazil on the border with Bolivia, who requested a re-analysis of Closed Fishing Season regulations for different species (DORIA et al., 2008). Furthermore, regulatory agencies need to take into consideration the recommendations already shown in other studies, which can help reduce the impacts caused by overfishing and the destruction of fish habitat; factors critical to sustainability of natural stocks (SÁNCHEZ-BOTERO et al., 2006; CORRÊA et al., 2014; FREITAS et al., 2014).

If adequate management of fishing resources is not implemented, important commercial species like tambaqui may become increasingly threatened in its natural habitat, forcing higher and higher demands on aquaculture to satisfy consumer needs (PELICICE et al., 2017). In addition, fisher livelihoods may be lost, forcing some people to resort to other types of resource extraction to generate revenues, which may be even more environmentally unsustainable (INOMATA; FREITAS, 2015).

Conclusion

Although the results of this study showed variations in the volume of tambaqui seizures among the three different rivers analyzed over a 20-year period, these variations were small in comparison to the differences found between the 10-year periods before and after implementation of the Closed Fishing Season Law. Overall, there was a 24.4% decrease in the volume of tambaqui seized after implementation of the Law, which can be attributed to several factors, 1) reduction of tambaqui stocks in the area of study; 2) occurrence of great floods and dry periods influenced by the natural phenomena El Niño and La Niña, which strongly affected fish stocks in 2002-2003 and 2009, respectively; 3) poor enforcement of regulations, due to reductions in IBAMA personnel and; 4) difficult to patrol such a large area, including many remote locations.

Although compensatory payments for fishers during the Closed Fishing Season appear to be a good incentive and may have helped contribute to the overall noted decrease in tambaqui seizures, in reality these payments may be simply encouraging more people to enter into the industry to take advantage of this benefit, while at the same time continuing to disregard fishing prohibitions aimed at protecting the sustainability of tambaqui stocks. In order to protect this fishery, a re-examination of current policies is urgently needed, as well as allocation of more funds for conservation management initiatives.

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